revised version
November 2005

HORIZONTAL - 15-2
Electrical Conductivity

Desk study to assess the feasibility of a draft horizontal standard for electrical conductivity

Lars Johnsson[1], S. Ingvar Nilsson[1] and Per Jennische[2]

[1]Department of Soil Sciences, Box 7014
[2]Rector's office, Box 7070
Swedish University of Agricultural Sciences (SLU), SE-750 07 Uppsala Sweden

Acknowledgement

This work has been carried out with financial support from the following EU Member States: UK, Germany, France, Italy, Spain, Nordic countries, Netherlands, Denmark, Austria, EU DG XI and JRC, Ispra.

Contents

List of tables

Summary

An international standard for EC determination in soils already exists. However, this is not the case for EC determination in bio-waste (compost) or sludge. The standard for soils is based on the use of dry samples. For EC determinations in compost and sludge the use of fresh samples is probably more suitable. The dilution factor or mass ratio (water:solid) during water extraction is of great importance for the final result and needs to be standardized. The ratio for soil is 5:1 and for compost and probably also for sludge the recommended mass ratio could be 8:1 or even 10:1. At higher ratios an additional favourable factor is that the samples normally only need to be centrifuged to get a suitable extract for the EC measurement. The time needed for equilibration or shaking when extracting electrolytes is 30 minutes for soils as well as for compost and sludge.

Introduction

Electrical conductivity (EC) is a numerical expression of the ability of an aqueous solution to carry an electrical current. It is generally related to the total solute concentration and can be used as a quantitative expression of dissolved salt concentration, even though it is also affected by the mobility, charge and relative concentration of each individual ion present in the solution. In addition to EC determinations on soil, there is also an increasing need for standardized methods for other substrates such as biowaste (i.e.compost) and sludge which are increasingly used to improve soil properties. The aim of this desk study is to look for already existing standards for measuring EC in different substrates, and to evaluate the need for modifications.

Existing standards or draft standards

To date there are standard methods for determining EC in soils but for sludge and biowastes (compost) there is much less uniformity concerning the methods used. The described methods differ with respect to pretreatment of the samples (fresh or dry), dilution ratios (water:solid) including saturated soil pastes, the time used for equilibration and the use of filtered or non-filtered samples (Table 1). This report starts with a description of an international standard for EC determination in soils followed by a review in which comparisons are made of the effects of different dilution ratios on EC determinations in compost (probably also valid also for sludge) (Van der Gheynst et al. (2004).

Table 1 Methods used to measure electrical conductivity (EC) of compost samples (from Van der Gheynst et al., 2004)

Table 1. Methods used to measure electrical conductivity (EC) of compost samples (from Van der Gheynst et al., 2004)	
Sample preparation	
Dilute compost with water using a mass ratio of 7.5:1(water:dry compost). Shake for 16 hours, filter and measure EC of filtrate.	Avnimelech et al., 1996
Saturated paste method. Dilute compost with distilled water to achieve a compost-water paste. Let sample sit for 4 hours. Filter paste using a highly retentive filter and measure EC of filtrate.	Campell et al., 1997
Shake sample mechanically with double distilled water for one hour using a mass to volume ratio of 10:1 (water:solid). Centrifuge sample at 10 000 rpm and filter through a 0.45 µm membrane filter.. Measure EC of extract.	Fang & Wong, 1999
Dilute compost with distilled water using a mass ratio of 5:1(water:compost). Measure EC of liquid extract.	Papadimitriou et al., 1997
Dilute compost with distilled water using a mass ratio of 5:1(water:dry compost). Shake mechanically for 20 minutes. Measure EC in slurry or extract.	Thompson et al., 2002
Modified saturated medium extract method. Mix growth medium (compost) with distilled water until it is just satutated. Incubate for 30 minutes. Place in a nylon mesh bag, squeeze extract from the bag and store on ice. Centrifuge extract at 10 000 rpm for 15 minutes, filter extract through a 0.45 µm membrane filter and measure EC	Grebus et al., 1994
Extract compost with water using a volume ratio of 1:1.5 (water:compost) and measure EC	Sonnerveld et al., (1974) in Spiers & Fiejte, 2000

Soil

For soils there is a Swedish standard for conductivity measurements, (SS-ISO 11 265:1996). This standard is based on the international standard ISO11265:1994, 'Soil quality – Determination of specific electrical conductivity'. The international standard is applicable to all types of air dried soils. The Standard specifies an instrumental method for routine determination of electrical conductivity in aqueous soil extracts. The determination is carried out to obtain an indication of the content of water-soluble electrolytes in the soil.

Measuring procedure

20.00 g of dry soil (grain size less than 2 mm) is added to 100 ml distilled water (maximum EC 0.2 mS m^{-1} at 25 °C) in a 250 ml borosilicate or polyethene bottle. The mass ratio will be 5:1 (water:soil). The ratio is chosen to get a suitable extract from all soil types including soils with a high organic matter content. The bottles are shaken in a horizontal position for 30 minutes at 20 °C and the extracts are immediately filtered through highly retentive filters with a low ash content. EC is measured with a temperature adjustment to 25 °C. The EC of an included blank sample should not exceed 1 mS m^{-1}.

Conductivity instrument

The conductivity instrument is equipped with a conductivity cell. It should be possible to switch between different measuring ranges. The instrument should have an automatic temperature compensation device and the precision of each measurement should be ± 1 mS m^{-1} at 20 °C. It is also an advantage if the cell constant is adjustable.

Control of the cell constant

The cell constant of the instrument is controlled by using KCl solutions with known EC values: 1290 mS m^{-1} (0.1 mol L^{-1}), 277 mS m^{-1} (0.020 mol L^{-1}) and 141 mS m^{-1} (0.010 mol L^{-1}), all at 25 ^{o}C.

Interferences

Polluted electrodes or air bubbles may compromise the accuracy of the measurements. When EC < 1 mS m^{-1}, atmospheric carbon dioxide (CO_2) or ammonia (NH_3) may have an influence on the measurements .

EC measurements in compost

The following section is a review of an investigation conducted by Van der Gheynst et al. (2004) concerning the effects on the determination of EC in compost material of (1) different mass ratios (compost: water) and (2) different equilibration times. The observed effects will probably be valid for sludge as well.

In this investigation 4 composts were used, all with a pH > 7. The samples were sieved through a 7 mm screen and stored at -20 °C until analysis. The determination of EC was made on “fresh” samples (no drying). The water content varied between 28 and 48 % of the wet weight.

Saturation paste method

Fifty to 100 g of composts was diluted with distilled-deionized water to achieve a saturated paste. The mass ratios at water saturation for the different composts were between 1.6 and 4.2. After water saturation the samples were equilibrated for 2.5 hours. After equilibration they were vacuum filtered and EC was immediately determined in the extracts. For all samples the coefficient of variation was between 20 and 25 %. The large variation was probably associated with the qualitative way of assessing water saturation and/or the heterogeneous compost material.

The influence of dilution on EC measurements

The dilutions or mass ratios (water:compost) used in the investigation were 3:1, 5:1, 6:1, 7:1, 8:1, 10:1 and 12:1. Extracts could be readily obtained using the 5:1 dilution ratio for 3 out of 4 compost samples. To get water extracts from all 4 composts the minimum ratio 6:1 was needed. The coefficients of variation of the EC measurements made on quantitatively diluted samples were less than 10 % and the average value was less than 1 %. At a lower mass ratio than 8:1 EC became lower than expected, suggesting either that salts were incompletely extracted at low dilution ratios or that the salts did not diffuse fast enough from the particle interiors to the water extractant.. The authors claimed that a mass ratio of 10:1 had at least two advantages compared to the saturation paste method, (1) the dilution was homogenous throughout the sample which made the EC measurements more accurate and repeatable. and (ii) at a dilution ratio of 10:1, gravity filtration could be used rather than vacuum filtration for collecting the extracts which made the analyses fairly simple and less expensive. Similar results were found by Thompson et al. (2002) for a dilution ratio of 5:1.

Time needed for equilibrium (shaking time)

The influence of extraction time was tested by shaking compost samples with the dilution ratio 7:1 (water:compost) during 30 minutes or 1, 3 and 15 hours. There was probably no significant increase in EC when the extraction time was extended from 30 minutes to 1 hour or 3 hours. The increase actually found between 3 hours and 15 hours was thought to be due to biological activity during the extraction or to the increased time for diffusion of salts from the interior of large compost particles. The conclusion was that since no significant difference in EC was observed between samples extracted for 30 minutes or 3 hours and since the biological activity was difficult to control during the extraction, the most suitable time for extraction was likely to be 30 minutes.

Evaluation of drafting a horizontal standard

Critical points

From the method descriptions and the reported results in the investigations presented above it seems that the pretreatment of samples and the dilution ratio are the two most critical points to consider to achieve a horizontal standard for EC determinations on soils and composts. First, the effect on EC of using fresh or dried samples is not clarified. Second, the necessary dilution of the soil samples seems to be lower than for compost and probably also lower than for sludge.

Pretreatment of samples

Fresh samples will probably give the most reliable EC measurements but may also contribute to more complicated and impractical analytical routines. A test on the effects on EC of drying the samples compared to EC on fresh samples should be performed.

Dilution effects and shaking time

The dilution ratio should be wider than that of a saturation paste. For soils the recommended dilution factor is 5:1 and for compost and sludge 10:1. In both cases a wide dilution ratio will be necessary to get a complete dissolution of electrolytes and to be able to use simple gravity filtration. The time needed for extraction should be set at 30 minutes.

Measurement of electrical conductivity

The measurements of EC regardless of substrate type could be performed according to the standard described for soils, SS-ISO 11 265 (see above)

Recommendations

For soils, dry samples are currently used both according to the international and the Swedish standard. For compost and sludge no international standards exist but from the investigation made by Van der Gheynst et al. (2004) fresh samples seem to be more suitable than dry samples. However, a simple test on the influence on EC of using dry versus fresh samples would clarify which pretreatment should be preferred.

The dilution or mass ratio (water:solid) during the extraction is very important for the resulting EC value due to the influence of the ratio on the solubility of the ions in the soil solution. The ratio therefore needs to be standardized. For soils the ratio of 5:1 (water:soil) is recommended in the international standard. Van der Gheynst et al. (2004) recommended a ratio of at least 8:1 or even 10:1 for compost. Besides the positive effect on the solubility of ions with different specific electrical conductivity, a high ratio will make the EC determinations both simpler and cheaper because only gravity filtration is needed to obtain an extract suitable for the EC measurement.

For soils, compost and probably for sludge as well, the equilibrium or shaking time needed is 30 minutes.

References

Avnimelech, Y., Bruner, M., Ezrony, I., Sela, R. and Kochba, M. 1996. Stability indices for municipal solid waste compost. Compost Science & Utilization, 4 , 13-12.

Campell, A.G., Folk, R.L. and Tripepi, R.R. 1997. Wood ash as an amendment in municipal sludge and yard composting processes. Compost Science & Utilization, 5 , 62-73.

Fang, M. and Wong, J.W.C. 1999. Effect of lime amendment on availability of heavy metals and maturation in sewage sludge composting. Environmental Pollution, 106, 83-89.

Grebus, M.E., Watson, M.E. and Hoitink, H.A.J. 1994. Biological, chemical and physical properties of composted yard trimmings as indicators of maturity and plant disease suppression. Compost Science & Utilization, 1 , 57-71.

ISO 11 265:1994. Soil quality – Determination of specific electrical conductivity. Geneva, Switzerland.

Papadimitriou, E.K., Chatjipavlidis, I. Balis, C. 1997. Application of composting to olive mill wastewater treatment. Environmental Technology, 18, 101-107.

Sonnerveld, C.J., van den Ende, J. and van Dijk, P.A. 1974. Analyses of growing media by means of a 1:1.5 volume extract. Communications in Soil Science and Plant Analysis, 5, 193-202.

Spiers, T.M. and Fiejte, G. 2000. Green waste compost as a component of soilless growing media. Compost Science & Utilization, 8 (1), 19-23.

SS-ISO 11 265:1996. Markundersökningar – Bestämning av den elektriska konduktiviteten. Stockholm, Sweden.

Thompson, W., Leege, P., Milner, P. and Watson, M. 2002. Test method for examination of compost and composting. The US Composting Council, US Government Printing Office. CDROM.

Van der Gheynst, J.S., Pettygrove, S., Dooley, T.M. and Arnold, K.A. 2004. Estimating electrical conductivity of compost extracts at different extraction ratios. Compost Science & Utilization, 12 , 202-207.